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PROCEEDINGS OF THE 33RD ANNUAL TUNA CONFERENCE

by

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PROCEEDINGS OF THE

33RD ANNUAL TUNA CONFERENCE

University of California Conference Center
Lake Arrowhead, California

May 16-19, 1982

Samuel F. Herrick, Jr., Chairman
Southwest Fisheries Center
National Marine Fisheries Service, NOAA
La Jolla, California 92038

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CONTENTS

		Page
PREFACE		iii
CONFERENCE AGENDA		iv
ABSTRACTS		
Geomagnetic orientation and navigation by tunas	Andrew Dizon	1
North Pacific albacore migration and fishery model	L. J. Bledsoe	2
An anecdotal report of California albacore and sea surface temperature distributions in the 1981 fishing season	Paul Sund	3
Results from an investigation to evaluate the potential for establishing a U. S. fishery on North Pacific albacore during the winter months in the eastern Pacific Ocean	R. Michael Laurs	4
U. S. demand for canned tuna	Dennis M. King	5
A linear model to standardize catch rates for yellowfin tuna in the eastern Pacific Ocean	Richard Punsly	7
Use of satellite imagery in albacore tuna oceanography studies	R. Michael Laurs	9
Metabolic rate of albacore tuna *Thunnus alalunga*	J. B. Graham and R. Michael Laurs	11
Atlantic bluefin tuna-oceanography-remote sensing: an update	Mitchell Roffer, Francis Williams and H. M. Carle	12
A sensitivity analysis of the western Atlantic bluefin tuna stock assessment	Ramon J. Conser and Joseph E. Powers	13
Age studies on northern bluefin tuna in the Pacific Ocean	Terry Foreman	14
Growth of eastern Pacific yellowfin tuna based on otolith increments	A. Wild	15

CONTENTS - Continued

		Page
Daily energy consumption in eastern Pacific yellowfin tuna	Robert J. Olson	16
Determination of probability distributions for Atlantic yellowfin tuna yield per recruit values from stochastically generated cohorts	Ronald Rinaldo	17
Obtaining information on dolphin reproduction from aerial photography	Michael D. Scott, Wayne L. Perryman and Philip Hammond	18
Some aspects of the biology of black skipjack	Kurt M. Schaefer	19
Estimating skipjack population turnover from tag returns	Pierre Kleiber	21
Surface tuna fisheries in New Caledonia	Francois Conand and Michel Kulbicki	22
Albacore trolling exploration in the South Pacific during February 1982	Jean-Yves Le Gall, Jean-Pierre Hallier, Francois Gallet and Henri Wallico	23
Management realities attending the distribution of tuna and billfish resources in the western and central Pacific Ocean	H. Burne Hill	24
Rudiments for managing tuna and tuna-like fish in the central and western Pacific	Justin Rutka	25
APPENDIX 33rd Tuna Conference Participants		26

PREFACE

The Tuna Conference, held annually since 1949, provides an opportunity for individuals, having an interest in tuna resources worldwide, to meet and informally discuss current topics and research related to tunas and tuna fisheries. The Conference is sponsored by the California Department of Fish and Game, the Inter-American Tropical Tuna Commission, and the Southwest Fisheries Center of the National Marine Fisheries Service.

The 33rd Tuna Conference was held at the University of California Conference Center, Lake Arrowhead, California from May 16 to 19, 1982. Sixty-nine people attended the Conference and participated in discussions covering current research on the population biology of tunas and its contribution to resource assessments and fishery evaluations, current research on environmental factors affecting tuna abundance and availability, and tuna fisheries managment and development. Abstracts of the presentations given at the Conference are included in this Proceedings.

I would like to thank Mr. Doyle Hanan, California Department of Fish and Game, Dr. Robert Olson, Inter-American Tropical Tuna Commission, Dr. Andrew Dizon, Southwest Fisheries Center, and Dr. Alex Wild, Inter-American Tropical Tuna Commission, for serving as session conveners during the 33rd Tuna Conference.

The elected chairman for the 34th Tuna Conference is Dr. Robert Olson of the Inter-American Tropical Tuna Commission, La Jolla, California.

Samuel F. Herrick, Jr.
Chairman

33RD TUNA CONFERENCE
LAKE ARROWHEAD, CALIFORNIA
May 16-19, 1982

A G E N D A

Sunday, May 16

15:30 - 18:00	Registration
18:00	Dinner
19:30	Reception

Monday, May 17 10:00 - 12:00, 13:30 - 16:30

Opening remarks and consideration of agenda.
Sam Herrick, National Marine Fisheries Service, La Jolla

SESSION CONVENER: DOYLE HANAN, California Department of Fish and Game, La Jolla

Geomagnetic orientation and navigation by tunas - Andrew Dizon, NMFS, La Jolla

North Pacific albacore migration and fishery model - L. J. (Sam) Bledsoe, NMFS, Seattle

SESSION CONVENER: ROBERT OLSON, Inter-American Tropical Tuna Commission, La Jolla

An anecdotal observation of California albacore catch and sea surface temperature in the 1981 season - Paul Sund, NMFS, Monterey

Results from an investigation to evaluate the potential for establishing a U.S. fishery on north Pacific albacore during the winter months in the eastern Pacific Ocean - R. Michael Laurs, NMFS, La Jolla

U. S. demand for canned tuna - Dennis King, ERG, San Diego

A linear model to standardize catch rates for yellowfin tuna in the eastern Pacific Ocean - Richard Punsly, IATTC, La Jolla

A G E N D A Continued

Use of satellite imagery in albacore tuna oceanography studies - R. Michael Laurs, NMFS, La Jolla

- Dinner -

DEMONSTRATION OF THE NORTH PACIFIC ALBACORE MIGRATION AND FISHERY MODEL

Tuesday, May 18 09:00 - 12:00, 13:30 - 16:30

SESSION CONVENER: ANDREW DIZON, National Marine Fisheries Service, La Jolla

Metabolic rate of albacore tuna Thunnus alalunga - R. Michael Laurs, NMFS, La Jolla

Atlantic bluefin tuna-oceanography-remote sensing: an update - Mitchell Roffer, University of Miami, Miami

A sensitivity analysis of the western Atlantic bluefin tuna stock assessment - Ramon Conser, NMFS, Miami

Age studies on northern bluefin tuna in the Pacific Ocean - Terry Foreman, IATTC, La Jolla

Growth of eastern Pacific yellowfin tuna based on otolith increments - Alex Wild, IATTC, La Jolla

SESSION CONVENER: ALEX WILD, Inter-American Tropical Tuna Commission, La Jolla

Daily energy consumption in eastern Pacific yellowfin tuna - Robert Olson, IATTC, La Jolla

Determination of probability distributions for Atlantic yellowfin tuna yield per recruit values from stochastically generated cohorts - Ronald Rinaldo, NMFS, La Jolla

Obtaining information on dolphin reproduction from aerial photography - Michael Scott, IATTC, La Jolla

Some aspects of the biology of black skipjack - Kurt Schaefer, IATTC, La Jolla

Estimating skipjack population turnover from tag returns - Pierre Kleiber, South Pacific Commission, New Caledonia

Wednesday, May 19 09:00 - 12:00

SESSION CONVENER: SAM HERRICK, National Marine Fisheries Service, La Jolla

Tuna fisheries in New Caledonia and surface albacore in the south Pacific - Francois Conand, ORSTOM, New Caledonia

Management realities attending the distribution of tuna and billfish resources in the western and central Pacific Ocean - H. Burne Hill, University of Washington, Seattle

Rudiments for managing tuna and tuna-like fish in the central and western Pacific - Justin Rutka, Western Pacific Fishery Management Council, Hawaii

Business Meeting

1. Date and site of next meeting
2. Selection of Chairperson for 34th Tuna Conference
3. Other business

GEOMAGNETIC ORIENTATION AND NAVIGATION BY TUNAS

Andrew Dizon

Southwest Fisheries Center
National Marine Fisheries Service, NOAA
La Jolla, California 92038

Perhaps more than any other migrating animals, pelagic fish need a reliable reference cue. There is none better for deep swimming aquatic animals than those furnished by the geomagnetic field. It can provide not only compass direction but time cues and local piloting information to the sufficiently sensitive animal. The earth's magnetic field has been shown reliably to influence behavior and orientation in a wide variety of organisms. Yet there has been only a handful of studies demonstrating successful condition to magnetic fields. Most of these conditioned responses have been very difficult to obtain or have failed subsequent replication attempts. Work of my colleagues and myself, with Thunnus albacares, is an exception. We have shown that these tropical tunas are easily conditioned to earth-strength fields and that they possess magnetite in their ethmoid sinuses in sufficient quantities to serve as the basis for a highly sensitive magnetoreception system.

NORTH PACIFIC ALBACORE MIGRATION AND FISHERY MODEL

L. J. (Sam) Bledsoe

University of Washington
Seattle, Washington

A hybrid differential equation/discrete event model for North Pacific albacore migration and fisheries has been computer implemented with data representative of the U. S. and Japanese fisheries during the 1970's. The model is intended to be used in testing hypotheses concerning albacore population dynamics, migration direction and timing and fishery availability. Particularly, the model is designed to be used to test the validity of hypotheses concerning the impact of environmental variables upon the above fishery related parameters. Hypothesis validity is indicated in terms of goodness-of-fit parameters, principally generalized correlation coefficients, to historical data sets. The coefficients are calculated in terms of area, time and fishery specific values to allow detailed examination of sub-hypotheses and model parameter values. Model results are depicted on a microcomputer based color graphics display showing the population and fishery status and migration routes being simulated.

Currently the model is being configured in an environment independent version in order to determine a baseline predictability for the system. This will be used for comparison with environmentally driven versions to be implemented later. The studies are being conducted by a multi-disciplinary team from the Southwest Fisheries Center, NMFS.

AN ANECDOTAL REPORT OF CALIFORNIA ALBACORE AND SEA SURFACE TEMPERATURE DISTRIBUTIONS IN THE 1981 FISHING SEASON

Paul Sund

Pacific Environmental Group
National Marine Fisheries Service, NOAA
Monterey, California 93942

Long-term monthly mean sea surface temperature distributions are compared with the monthly means of 1981. The seasonal shift from zonal to meridional orientation is seen in both data sets; however, in 1981 the oceanic "albacore isotherms" were positioned at a substantial distance offshore in northern California until mid-September. This offshore location was due to persistent upwelling of cool coastal waters at the coastline. With the relaxing and cessation of upwelling, the "albacore isotherms" repositioned themselves closer to the coast. Observations of sea surface temperature and fish locations at the time of this translocation, made simultaneously from a survey aircraft, indicated that albacore were located in warm oceanic waters seaward of cool upwelled coastal water, and that the fish distributions changed along with the isotherms. That the fish distributions changed in response to the environmental changes also was supported by logged catch distributions of the U. S. jigboat fleet (data available after presentation of this report).

RESULTS FROM AN INVESTIGATION TO EVALUATE THE POTENTIAL FOR ESTABLISHING A U. S. FISHERY ON NORTH PACIFIC ALBACORE DURING THE WINTER MONTHS IN THE EASTERN PACIFIC OCEAN

R. Michael Laurs
Southwest Fisheries Center
National Marine Fisheries Service, NOAA
La Jolla, California 92038

Six chartered commercial fishing vessels conducted exploratory longlining operations for albacore tuna in an area centered about 1,000 to 1,500 miles west of San Diego during January-February 1982. A combined total of 112 sets was made during the survey. Each of the vessels typically set 800 to 1,400 hooks in and about thermocline depths of 350 to 700 feet. A total of 70,939 pounds of albacore and 7,834 pounds of bigeye tuna was caught. Seven percent of the total albacore landings were fish taken on trolling gear. Individually the vessel landings ranged from 24,274 to 6,102 pounds of albacore and bigeye combined. Daily longline catches ranged from 0 to 136 albacore. The mean catch per set for all vessels was 31 albacore, equivalent to 3.2 fish per 100 hooks (3.4 if bigeye tuna are included). The average hook rate varied among vessels from 1.6 to 4.8 per 100 hooks. There was some fish loss due to line twisting, part of which occurred as the gear broke surface. This problem varied among vessels and can be largely reduced by modifications in gear and handling. The longline catches fell into two size groups, 14-18 pounds and 22-27 pounds.

Thirty-five days were allocated to each charter vessel; of these, 12 to 13 days were used in transit during which the vessels trolled for albacore. Of the 22-23 days on the longline fishing grounds, 3 to 4 were lost to rough weather, except for one vessel which was able to operate under such conditions. One vessel conducted acoustic tracking experiments for 4 days and another spent an additional 4 days trolling.

The results of this study show that the U. S. albacore fishery can be extended to operate during winter months using longline fishing techniques in an area where the fleet has not traditionally fished. This potential for a mid-winter fishery exists as an important alternative to other winter fisheries or remaining idle. An additional factor of importance is that fuel consumption was 40% to 50% below that typical of trolling operations.

U. S. DEMAND FOR CANNED TUNA

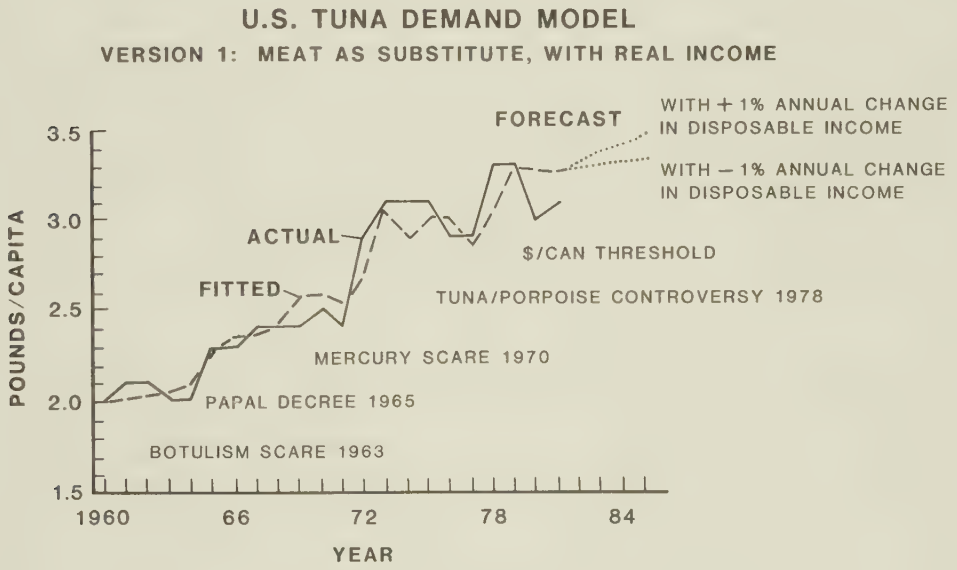
Dennis M. King

ERG Pacific, Inc.
San Diego, California

The consumption of tuna in the U. S. depends on the price of tuna, the price of substitute foods, and income. The relative impact of these factors and the likely outcome of tuna pricing policies can be estimated using the results of a time series analysis of consumption, price and income data.

The U. S. demand for canned tuna as reflected by per capita tuna consumption was estimated as a function of disposable personal income (DPI), the consumer price index (CPI) for tuna and the CPI for meat. Standard multiple regression techniques were applied to logged values of the independent and dependent variables.

Regression coefficients and summary statistics are presented in the following figure which also shows actual and fitted values of U. S. per capita tuna consumption for years 1960-1981.



U.S. TUNA DEMAND MODEL

$$Y = -4.983 - .353 X_1 + .595 X_2 + .572 X_3$$

(4.473) (2.112) (3.239) (2.597)

SUMMARY STATISTICS

$R^2 = .931$
$F(3,18) = 81.497$
Durbin-Watson = 1.515
Standard error = 0.49
N = 22 D.F. = 18

VARIABLES

Y = Per capita tuna consumption (lbs)
X^1 = Retail price index - tuna
X^2 = Adjusted disposable per capita income
X^3 = Retail price index - meat

(The numbers in parentheses are t statistics.)

The regression equation seems to explain 93% of the annual changes in U. S. tuna consumption. All regression coefficients are of the expected sign, each is significant at over 90% confidence, and results can be interpreted as follows:

A 10% increase in tuna prices can be expected to result in a 3.5% decline in per capita tuna consumption.

A 10% decline in the price of meat can be expected to result in a 5.7% decline in per capita tuna consumption.

A 10% decline in income can be expected to result in a 5.9% decline in per capita tuna consumption.

Results show that aggressive tuna pricing in periods of falling income and declining beef and poultry prices account for some portion of the tuna industry's slump during 1980/1981. Although U. S. tuna demand is relatively unresponsive to changes in tuna prices, there is a "threshold" price around $1 per can where consumer resistance increases. The decline in retail sales caused by changes in economic conditions and other factors during 1979-1981 reduced U. S. raw tuna requirements by about 7,000 short tons.

A LINEAR MODEL TO STANDARDIZE CATCH RATES FOR YELLOWFIN TUNA IN THE EASTERN PACIFIC OCEAN

Richard Punsly

Inter-American Tropical Tuna Commission
La Jolla, California 92038

A linear model for estimating yellowfin tuna abundance based on catch rates is presented. In the linear model, fishing effort is defined as the elapsed time between successful sets, and catch rates are standardized for a range of vessel characteristics, environmental conditions, and fishing mode.

The vessel characteristics used were capacity (0-499 tons, 500-999 tons, and 1000 tons and over), speed, age, whether or not aerial assistance was available, and net length and depth; the environmental variables were sea-surface temperature and wind speed. The fishing mode was a classification of the 5-degree area-month strata as those in which two-thirds or more of the catch of yellowfin or skipjack tuna was taken from porpoise-associated schools, those in which two-thirds or more was from log or schoolfish sets, or those in which neither type predominated. This classification was further divided by area (inside or outside of the Inter-American Tropical Tuna Commission's Yellowfin Regulatory Area (CYRA), and quarters of the year. Because some categories in the final classification have few or no observations, only three combinations of area and fishing mode, that is, schoolfish and log strata inside the CYRA, porpoise strata inside the CYRA, and porpoise strata outside the CYRA, were used in the linear model.

The effect of these parameters on the logarithm of catch rates of yellowfin was investigated using data from 1970 to 1980. Stepwise regression techniques were used to select a set of parameters which had the most important effects on catch rates. In order of importance (largest associated sum of squares) in the final model these were year, year/stratum interaction, vessel speed, sea-surface temperature, aerial assistance, stratum, net depth in stratum 1, quarter, sea surface temperature squared, sea surface temperature cubed, net length, stratum/quarter interaction, and capacity plus capacity/stratum interaction.

For all the strata there is a considerable decline in catch rates since 1970, the most marked being for school fish and log strata inside the CYRA, which in 1980 was only 27% of its value in 1970. The pattern of the decline has been different for each strata type; porpoise strata inside the CYRA have shown a fairly consistent decline since 1970, whereas outside the CYRA the catch rate in porpoise strata did not decline until after 1973. Exploitation of the outside area did not start until the late 1960's and it was not until 1972 that the catch reached 40,000 tons. The large drop in catch rate in school fish and log strata in 1971 and the subsequent recovery in 1972 was too large a fluctuation to be caused only by changes in abundance. It is most

likely that this shows a change in vulnerability that was not associated with the standardizing factors used in the model.

USE OF SATELLITE IMAGERY IN ALBACORE TUNA OCEANOGRAPHY STUDIES

R. Michael Laurs

Southwest Fisheries Center
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La Jolla, California 92038

Experiments were conducted using ocean measurements made by satellites contemporaneously with observations made from ships at sea in an investigation of the small-scale migration patterns of albacore tuna in relation to oceanographic conditions.

NIMBUS CZCS and NOAA6 satellite AVHRR infra red thermal data were collected at the Scripps Institution of Oceanography Remote Sensing Facility in conjunction with field experiments where a) acoustic telemetering methods were used to track the horizontal and vertical movements of free-swimming albacore, and b) XBT observations were made to determine subsurface ocean thermal structure. Three albacore were tracked for approximately 24 hours and one for about 15 hours. The results showed: a) total distances tracked ranged from about 40 to 60 km with all fish remaining in the same parcel of warm water that was separated from waters to the north and inshore by a 4^{o}F temperature gradient, b) tracked fish spent most of the time in waters within and below the thermocline, and only small amounts of time in the upper mixed layer, c) the fish exhibited marked vertical excursions in depth, with a larger range during daytime hours than during nighttime hours, d) the fish spent the majority of the time in waters with temperatures considerably lower (about 45^{o} to 60^{o}F) than what has been generally believed to be the optimal temperature preference for albacore (60^{o} to 66^{o}F), and e) when undergoing vertical changes in depth the fish frequently within a 20 minute period passed through a vertical gradient of temperature amounting to 12^{o} to 15^{o}F or about 3+ times greater than the horizontal temperature gradient at the surface indicated by ship measurements and the IR thermal imagery.

These findings indicate that the causal factor(s) involved in the aggregation of tuna on the warm side of ocean surface temperature fronts, a phenomenon which has been observed on scientific cruises and is well known by fishermen, and has significant economic implications, may not be related to thermal-physiological mechanism(s) as has been previously suspected. Instead, it appears that a behavioral mechanism(s) related to feeding may be responsible. Measurements made by the CZCS in conjunction with the tracking study provide data which support this hypothesis.

The diffuse attenuation coefficient measured by the CZCS showed a gradient nearly coincident with the sea surface temperature gradient pattern, with lower values of k in the warmer waters and higher values in the cooler waters. The distribution of color boundaries indicated by the ratio of

blue:green color bands measured by the CZCS was also similar to the gradient pattern observed in the diffuse attenuation coefficient.

The results show that the albacore remained in water that had higher water clarity than adjacent waters. This suggests that water clarity as it affects the tuna being able to see its prey to feed may play a key role in the mechanism(s) underlying the aggregation of tuna on the warm side of ocean surface thermal fronts.

METABOLIC RATE OF ALBACORE TUNA *THUNNUS ALALUNGA*

J. B. Graham and R. Michael Laurs
presented by R. Michael Laurs

Southwest Fisheries Center
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La Jolla, California 92038

The oxygen consumption rates (VO_2) of 6 specimens (6 to 13 kg) of the albacore tuna *Thunnus alalunga* were measured at sea, using specimens collected 300 km west of San Diego, California (USA) during July and August 1981. Fish were tested in a closed continuous-flow respirometer where they swam at about 1.3 body lengths s^{-1} velocity in 15^{o} to 19^{o}C waters. The albacore tuna is a temperate pelagic species experiencing water temperatures from about 10^{o} to 20^{o}C and attaining a maximum weight of 55 kg. The VO_2 ranged from 1,249 to 3,336 ml h^{-1} (the mean VO_2 for the 6 fish was 2,228 ml h^{-1}); such values approach those of mammals of a similar size and are 3 to 4 times those of most active fishes (e.g. sockeye salmon). Among fishes, the only higher VO_2 values yet recorded were for the skipjack tuna *Katsuwonus pelamis*, a tropical species. The remarkably high metabolic rates of tunas are presumably correlated with their continuous swimming activity and the maintenance of endothermy. The exponent relating VO_2 to body weight (1.18), although large, is not statistically different from the exponents for most other active vertebrates.

ATLANTIC BLUEFIN TUNA-OCEANOGRAPHY-REMOTE SENSING: AN UPDATE

Mitchell Roffer, Francis Williams and H. M. Carle
Presented by Mitchell Roffer

Rosenstiel School of Marine and Atmospheric Science
University of Miami
Miami, Florida

The principal objective of the Atlantic bluefin tuna-oceanography-remote sensing program, supported by the National Aeronautics and Space Administration (NASA), is to contribute to fisheries forecasting and efficient utilization and management by integrating analyses of fisheries data with oceanographic data. Current analyses are designed to provide an improved description of indicator environmental conditions coinciding with the "onset" and "end" of the bluefin tuna recreational fishery in North Carolina-Virginia coastal waters. Results indicate that the fishery for school size bluefin tuna (10-60kg) commences within a week of the widening of the surface mixed layer, such that the depth of the 19^{o}C isotherm is equal to or greater than 4 meters. At the start of the season bluefin tuna are observed swimming almost exclusively at the surface and catch rates increase from zero to greater than four bluefin/tuna per boat day. During the peak season the thermal habitat widens and bluefin tuna are observed less frequently at the surface. At this time the depth of the 19^{o}C isotherm is 7-10 meters with temperatures of 20-21^{o}C most common in the surface mixed layer. At the "end" of the season (catch rates equal zero) surface mixed layer temperatures are equal to or greater than 24^{o}C and bluefin tuna move to other areas which allow for optimal physiological functioning. Data on oxygen saturation, chlorophyll biomass and forage availability, for the same time periods are currently being analyzed.

A SENSITIVITY ANALYSIS OF THE WESTERN ATLANTIC BLUEFIN TUNA STOCK ASSESSMENT

Ramon J. Conser and Joseph E. Powers

Southeast Fisheries Center
National Marine Fisheries Service, NOAA
Miami, Florida 33149

In this study, an extensive list of sensitivity scenarios were examined using virtual population analysis, to create a range of uncertainty about the estimates of trends in population abundance of western Atlantic bluefin tuna. These scenarios included alteration of the natural mortality rate, directed effort estimates, starting fishing mortality (F) vectors, catch bias, catch variability, and joint perturbations of the more sensitive parameters. In all of the sensitivity scenarios examined there was a decline in abundance over the years since 1960. In most cases the decline was very large, indicating the possibility of considerable risk to the stock and to the fishery. The range of percent stock decline from 1960 to 1980 was from 4 to 40 percent of the 1960 level.

Forward projections of trends in stock biomass showed that the range of uncertainty widened as the projections were made further into the future. However, the best estimates of the stock's status imply that the stock will not grow very quickly, even if no fishing occurs. If catches of 800 mt are taken annually, then the stock will continue to decline. However, our uncertainty about this conclusion is relatively greater than in the back projection of trends. The sensitivity tests showed that in most cases the growth rate of the stock will not be large under any management scenario.

Surplus production estimates for 1982 from the sensitivity analysis showed a relatively greater amount of variability due to the dynamics of non-equilibrium age distributions. The range of uncertainty encompassed the zero surplus production value (-1822 mt to 670 mt); surplus production using updated catch statistics still fell within this envelope.

AGE STUDIES ON NORTHERN BLUEFIN TUNA IN THE PACIFIC OCEAN

Terry Foreman

Inter-American Tropical Tuna Commission
La Jolla, California 92038

An ageing study was undertaken in 1980-81 to determine the age composition of the catch of northern bluefin tuna made in the eastern Pacific, through analysis of hard parts for temporal marks. Tagging studies conducted off Japan in 1981 which included injection with oxytetracycline have provided 27 bluefin 19-48 cm fork length with marked otoliths. Analysis of the microstructure of these otoliths from the mark to the edge has shown the increment to time relation to be $I = 0.3756+0.9809\ DL$ where $I=\bar{x}$ of 5 counts on the otolith and DL= days at liberty, and is not significantly different from a 1:1 relationship. During the reading, many subdaily increments were encountered, probably due to the rapid growth of the fish at that stage. Validation of daily periodicity at this and larger sizes is important, as total counts from fish over the size range would estimate age at a higher degree of precision and accuracy than other "annulus"- based methods. Ages derived from whole otolith counts of daily increments can then be compared to those obtained by analysis of other hardparts, such as scales, spines, finrays, and vertebrae, which have been collected over the last two seasons.

Preliminary analyses of samples from the 1980 northern bluefin tuna catch in the eastern Pacific revealed that the majority of the scales and spines examined had two "annual" marks. This coincides with previous work for fish of the same size category (70-80 cm). Future work will attempt to validate age in a larger size range and ascertain which hardpart is easiest to use in age determination.

Ageing studies from tagging of small bluefin tuna (15-25 cm at release and 37-48 cm at recapture) yield growth rate estimates of approximately 6-8 cm per month. Studies of larger fish (~50 cm at tagging) has shown an interesting difference in growth rate estimates between fish recaptured near Japan (2.28 cm/mo) and those migrating to the eastern Pacific (1.62 cm/mo).

GROWTH OF EASTERN PACIFIC YELLOWFIN TUNA BASED ON OTOLITH INCREMENTS

A. Wild

Inter-American Tropical Tuna Commission
La Jolla, California 92038

Relationships are developed between a variety of growth variables of eastern Pacific yellowfin tuna and the total number of increments on their sagittal otoliths. The variables are fork, predorsal and head lengths, net and gross weight, otolith weight and the length of the counting path from the otolith primordium to the postrostrum. The sample (n = 196) includes approximately 15 fish in each 10 cm interval in the commercial fork-length range from 30 to 170 cm. Increment counts are taken from cellulose acetate replicas of the etched otoliths. Based on the partially justified assumption that each increment is equal to a day, equations are developed to express each variable as a function of time. Predictive relationships for increments, and possibly time, based on fork length and head length measurements are also included. The results apply to yellowfin growth in the period from 1977 to 1980 and in the region north of the equator and between 95^{o} and 137^{o}W longitude.

DAILY ENERGY CONSUMPTION IN EASTERN PACIFIC YELLOWFIN TUNA

Robert J. Olson

Inter-American Tropical Tuna Commission
La Jolla, California 92038

Estimates of daily food consumption by yellowfin tuna in nature are made by two independent methods. The total energy required by individual fish per day is predicted by means of an energy budget model updated by incorporating measurements of swimming velocities made during acoustic telemetry experiments. The total of the energy expenditures for maintenance, growth, and locomotion is assumed to equal approximately 80% of the caloric intake required per day, based on bioenergetics principles. The second method utilizes stomach samples in conjunction with laboratory measurements of gastric evacuation rates.

A brief outline of the feeding habits of yellowfin tuna caught in offshore areas of the eastern Pacific Ocean is presented. Frigate tunas (Auxis sp), cephalopods, and flyingfishes are the first, second, and third most important prey groups, respectively, in terms of the index of relative importance (IRI).

Size-specific estimates of calories consumed per fish-day generated by both methods are presented and related to comparable energy intake levels of other fishes. The energy budget yields higher consumption estimates than the feeding model, close to a level equal to three times the routine metabolic rate. The conservative food consumption estimates based on the feeding model, averaged over four age-classes, are converted to prey biomass. These values, partitioned by prey type, are multiplied by yellowfin age-specific population estimates for 1970 based on cohort analysis in order to derive purposely conservative estimates of food consumption by the Inter-American Tropical Tuna Commission's Yellowfin Regulatory Area population during 1970. The calculations indicate that at least 16,500 metric tons of food was eaten by the population per day, 6,637 metric tons of which were Auxis sp. A total of at least 6 million metric tons of food were consumed during the year, about 2.4 million tons of which were Auxis sp.

Hypothetical predator-prey feedback relationships are discussed in terms of possible predation by some of the food organisms of yellowfin tuna on young stages of yellowfin tuna.

DETERMINATION OF PROBABILITY DISTRIBUTIONS FOR YIELD PER RECRUIT VALUES FROM STOCHASTICALLY GENERATED COHORTS

Ronald G. Rinaldo

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A procedure to assess the variability about yield-per-recruit (Y/R) point estimates for each size at entry has been developed for a fishery characterized by a normally distributed catch at age that has been operating consistently over an extended period of time. The procedure is conducted as follows: a Monte Carlo simulation is applied to the catch for each age and a large number (≥1,000) of samples are generated. Each set of samples from the youngest through oldest age is considered a sample cohort and is run through the cohort and Y/R analyses. The procedure produces a range of normally distributed Y/R estimates. The coefficient of variation for Y/R estimates is much smaller than the coefficient of variation for the catch distributions from which they were generated. Values of the distribution parameters obtained through this procedure make it possible to test for significant differences in Y/R, given changes in the catch structure.

Further refinements to this procedure are expected to yield a relatively simple, consistent method for evaluating the significance of changes in Y/R, given changes in the underlying catch parameters.

OBTAINING INFORMATION ON DOLPHIN REPRODUCTION FROM AERIAL PHOTOGRAPHY

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An aerial photographic survey was conducted off the west coast of Mexico to acquire length frequency data on dolphin stocks affected by the tuna purse-seine fishery in the eastern tropical Pacific. The study was designed to develop and evaluate techniques for photographing dolphin schools, measuring lengths of dolphin images from aerial photographs, and using these data for calculating reproductive parameters. The camera systems onboard included a 230 mm format cartographic camera, two 115 mm format aerial reconnaissance cameras, and four Hasselblad 55 mm format cameras. The camera systems were mounted vertically in the deck of an AT-11 aircraft. Although all of these camera systems have been used successfully to collect imagery for length determination of large cetaceans, only the 115 mm format cameras produced photographs of adequate quality for dolphin length measurements. This was mainly due to the image motion compensation system which eliminated image smear caused by forward movement of the aircraft. Of the 100 schools photographed, 29 were of suitable quality for length measurement analysis. Due to their light grey color and unique swimming behavior, spinner dolphins (Stenella longirostris) were found to be more vulnerable to photographic sampling than the other species encountered. Preliminary analyses of some length data from schools of the Costa Rican race of spinner dolphins have revealed that groups of lengths of small animals can be identified which correspond to age groups approximately 6 months apart up to an age of 1 1/2-2 years. Analyses are proposed to try to describe the data using a limited age-structured model from which estimates of reproductive rate can be obtained.

SOME ASPECTS OF THE BIOLOGY OF BLACK SKIPJACK

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A life history study of black skipjack tuna (Euthynnus lineatus) was initiated in August 1980 with an intensive sampling program. In addition, E. lineatus have been tagged, along with yellowfin and skipjack tuna, during tropical tuna tagging cruises on chartered baitboats by the IATTC since 1979.

The principal catches of E. lineatus in 1981 were made in an area off Ecuador and Colombia between about 1^{o}N and 4^{o}N latitude, and east of 82^{o}W longitude. The landings in 1981 were 1,700 short tons.

Chi-square tests showed a significant departure from the expected 1:1 sex ratio for the total numbers of males and females, resulting from a dominance of males in the samples. Furthermore, chi-square tests of males and females grouped into 5 cm length intervals indicated a significant departure from the expected 1:1 sex ratio for fish greater than 50 cm due to a dominance of males.

Length and weight were measured from 3,267 E. lineatus captured by purse seiners from throughout the eastern Pacific during 1980 and 1981. The following linear regression was derived between the natural logarithm of the variables: log W= -11.3781 + 3.0683 log L, where W is weight (grams) and L is fork length (millimeters). The coefficient of determination, R^2, is 0.963.

The size composition of the catch for the past 6 years, along with the size composition of the catch in 1980 and 1981 by areas and by quarters, is presented. The average weight of the fish landed has been calculated for all areas combined, along with the average weights of fish for the geographical areas for which data are available. The estimate of the average weight of E. lineatus in the eastern Pacific in 1981 is 2.9 lbs or 1.3 kg.

Growth rate estimates derived from modal progression analysis and from returns of tagged fish from off Central America are presented. For fish between 31-49 cm fork length at the time of release which were tagged off Central America and were at liberty between 10-180 days we see an average growth rate of .37 mm per day (1.1 cm/month or 13.5 cm/year).

Migrations of E. lineatus which were tagged off the southern Mexico-Guatemala area and also on Cocos Ridge off Central America in 1979, and those tagged offshore Central America in 1981 are shown. Recpatured fish (3.5%) tagged in 1979 both off the southern Mexico-Guatemala area and also on

Cocos Ridge showed movements to the coast of Colombia. The recaptured fish (8.5%) tagged in 1981 off Central America also showed movements toward the coast in most cases.

ESTIMATING SKIPJACK POPULATION TURNOVER FROM TAG RETURNS

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In three years of tagging, the Skipjack Survey and Assessment Programme of the South Pacific Commission released approximately 140,000 tagged skipjack tuna, Katsuwonis pelamis, throughout much of the tropical and subtropical, central and western Pacific. From these releases almost 6,000 tags have been returned.

A tag return and attrition model was fitted to the observed monthly return rates from the aggregate set of all returns and to the return rates from individual fisheries for which catch statistics were available. Under a steady state assumption the resulting tag attrition estimate is equivalent to the population turnover ($month^{-1}$). In addition to the turnover, estimates were obtained of harvest rate ($month^{-1}$), throughput (tonnes/month), and standing stock (tonnes). In all cases the harvest rate was a small fraction of the turnover rate. The aggregate estimate of turnover was 0.19 $month^{-1}$ with a harvest rate of 0.004 $month^{-1}$.

The returns of tagged fish released in the area of one fishery and recovered in the area of another fishery were analyzed with a migration model. The results indicate that migration of adult skipjack tuna between neighboring fishing areas accounts for only a small part of the population turnover in the fishing areas.

SURFACE TUNA FISHERIES IN NEW CALEDONIA

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Since 1979 Japanese pole and line boats have fished regularly in the exclusive economic zone (EEZ) of New Caledonia during the southern summer. In September 1981 a New Caledonian company started pole and line fishing in the same area. Currently, the company operates one 300 ton pole-and-line vessel and two similar vessels are expected to begin fishing in June 1982. Comparisons between local and Japanese results are presented in Table 1.

American purse seiners made trials in the New Caledonian EEZ during the 1980 and 1981 fishing seasons (Table 2). In 1980 the number of unsuccessful sets was very high and the overall results rather bad. The 1981 campaign yielded better results, especially with regard to the number of successful sets.

The ORSTOM is in charge of studying the evolution of tuna fishing in the New Caledonia area. Aerial surveys with airborne radiometry are undertaken for this purpose, along with exploratory bait fishing campaigns. These investigations are coupled with the study of the biology of the main species involved. The effect of environmental factors on catches is also being investigated.

Table 1. Results of the Japanese and New Caledonian pole and line fishery for 1979-1982.

Southern summer season Oct. 15 - March 15	Japanese '79-'80	Japanese '80-'81	Japanese '81-'82	New Caledonian '81-'82
No of vessel	12	8	12	1
No of fishing days	337	101	152	65
Total Catch (M.T.)	3236	828	950	406
Catch per day	9.6	8.2	6.2	6.2

Table 2. Results of American purse seine trials conducted in the New Caledonian EEZ, 1980-81.

	No vessels	No days	Catch (M.T.) skipjack	Catch (M.T.) yellowfin	No sets	Percent successful sets	Average catch per successful set
1980 (May-June)	4	61	60	199	64	9	43
1981 (April-May)	2	25	139	146	14	36	55

ALBACORE TROLLING EXPLORATION IN THE SOUTH PACIFIC DURING FEBRUARY 1982

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An exploratory trolling cruise, organized by the ORSTOM Research Centers Papeete (Tahiti) and Noumea (New Caledonia), for albacore tuna was conducted onboard the R. V. Coriolis from November 11, 1981 (Tahiti) to March 4, 1982 (Noumea) in the south-central Pacific. During the last week of February fishing occurred in the area bounded by 38^{o}S to 42^{o}S latitude and 157^{o}W to 180^{o}W longitude. This exploratory cruise, demonstrated that immature albacore (from 42 to 94 cm fork length) are available to surface troll gear in the south-central Pacific during the austral summer.

The potential area for an albacore troll fishery is the frontal zone between central sub-tropical and sub-Antarctic water. The geographical extension of this latitudinal band, encompassing waters from 16^{o} to 19^{o}C, is relatively restricted and well defined through SST satellite imagery (GOSSTCOMP type). The summer thermocline (upper mixed layer well defined) and chlorophyll pigment content (1.5 mg/m^3) are factors contributing to the availability of albacore at the surface. During the 45 effective fishing hours on hydrological structures well suited to albacore occurrence, catch rates were from 1 to 2 albacore per fishing hour (for seven trolling lines). The catch rates suggest a scattered distribution (no sea birds). In this respect, the zone differs from important albacore tuna surface fishing grounds, such as, the N.E. Atlantic and the N.E. and N.W. Pacific.

MANAGEMENT REALITIES ATTENDING THE DISTRIBUTION OF TUNA AND BILLFISH RESOURCES IN THE WESTERN AND CENTRAL PACIFIC OCEAN

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Estimates of the distribution of the fishing effort of the Japanese tuna baitboat fleet and the Japanese and Taiwanese tuna longline fleets and of their catches of tuna and billfish were made using computer programs which interfaced with an apportionment analysis that assigned jurisdictional rights in cells of latitude and longitude within the western and central Pacific Ocean region (WCP). The portions of the region's total 1977 fishing effort (vessel days) and catch (tonnes) represented by individual marine zones and various combinations of marine zones were examined to assess the relative importance of specific coastal states, potential coalitions of WCP states and of international enclaves and high seas to the fishing activities of the three fisheries and to their major catch species. Three coalitions of marine zones are examined: the zones under the jurisdiction of states belonging to the South Pacific Forum Fisheries Agency (FFA) as of May 1982, of states belonging to the South Pacific Commission (SPC) and of the six Pacific island states with the highest portions of effort and catch in each category.

The implications of this type of distributional analysis for the biological and statistical management of the WCP tuna and billfish fisheries are clear. The management opportunities afforded by the large regional membership of the SPC, which includes all of the coastal states belonging to the FFA plus the Federated States of Micronesia, the Marshalls, Palau, the United States and France, are considerably improved over those of the FFA membership of Pacific island states. The importance of the international waters to the region's tuna and billfish fisheries, particularly the longline fisheries, is substantial and merits the inclusion of states whose fleets harvest the scombrid resources in these seas in any organization conducting biological and statistical fisheries management. Finally, the relatively large share of the catch of yellowfin, skipjack and southern albacore taken within the zones of a subregional selection of coastal states suggests a potentially enhanced managerial efficiency in the formulation of certain management policies in groups much smaller than the organization's full membership. It is felt, therefore, that the framework for the scientific management of tuna and billfish in the western and central Pacific Ocean should be that of a broadly-based "Article 64" organization.

RUDIMENTS FOR MANAGING TUNA AND TUNA-LIKE FISH IN THE CENTRAL AND WESTERN PACIFIC

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All of the principal market species of billfish and tuna, except for skipjack tuna, appear to be either fully exploited or almost fully exploited, and some species could be overfished. Yellowfin, albacore, and bigeye tuna appear to be nearly fully exploited by the longline fishery in the central and western Pacific. More longline effort on these species would likely result in only small catch increases and could possibly decrease catches. Blue marlin are over exploited. Striped marlin stocks in the central and western Pacific may be showing signs of a similar condition.

At the moment the U. S. appears to be preoccupied with tuna problems in the eastern Pacific and western Atlantic Oceans. There is no readily apparent policy nor a defined national interest in the tuna and tuna-like fisheries of the central and western Pacific.

The U. S. Fishery Conservation Zones surrounding American flag islands in the Pacific, the U. S. trust Territory of Micronesia, and the intervening high seas encompass nearly a fifth of the earth's surface. There are compelling biological, economic, and political reasons for placing more national attention on the pelagic fisheries of the region. Doing so would require marrying island interests in tuna and billfish to the interests of the United States tuna industry.

APPENDIX

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